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ABSTRACT

An experienced person, in such tasks as sonar detection and recognition, has a considerable superiority over a machine recognition system in auditory pattern recognition. However, people require extensive exposure to auditory patterns before achieving a high level of performance. In an attempt to discover a method of training people to recognize auditory patterns in an expeditious fashion, fifteen methods of teaching identification of complex sonar-like sounds were compared. These included whole and part methods in which subjects were trained on samples of whole sounds, received pre-training on components of the sounds, or were exposed to components in the context of whole sounds. The conditions included variations in the order in which training items were presented and in the kinds of verbal instruction given. Overall, the various part methods were not superior to training on whole sound items. The best of the part methods drew attention to only one feature of the whole sound. Some systematic orders of presentation showed no advantage over random order presentation. Verbal instruction drawing attention to cues and their value in classification did not prove effective. Among the various combinations of training procedures and state-of-the-art training techniques, the critical ingredient seems to be amount of exposure to instances of the recognition classes to be learned. (Author/JY)

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SONAR RECOGNITION TRAINING: AN INVESTIGATION OF WHOLE VS PART AND ANALYTIC VS SYNTHETIC PROCEDURES

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SONAR RECOGNITION TRAINING: AN INVESTIGATION OF WHOLE <u>VS</u>. PART AND ANALYTIC <u>VS</u>. SYNTHETIC PROCEDURES

ABSTRACT

A series of experiments is described in which fifteen methods of teaching identification of complex sonar-like sounds were compared. These included whole and part methods in which subjects were trained on samples of whole sounds, received pre-training on components of the sounds or were exposed to components in the context of whole sounds. The conditions included variations in order in which training items were presented and in the kinds of verbal instruction given.

Overall the various part methods were not superior tc training on whole sound items. The best of the part methods drew attention to only one feature of the whole sound. Some systematic orderings of presentations showed no advantage over random order presentation. Verbal instruction drawing attention to cues and their value in classification did not prove effective.

Among the various combinations of training procedures and state-of-the-art training techniques, the critical ingredient seems to be amount of exposure to instances of the recognition classes to be learned. Before further refinement in the training of this skill can be achieved a greater understanding of human perceptual learning is required.

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FOREWORD

This report deals with aspects of auditory pattern perception which remains a poorly understood area of human performance. The experienced human pattern recognizer, in such tasks as sonar detection and recognition, still maintains a considerable superiority over a machine recognition system. However, the human requires extensive exposure to auditory patterns before achieving a high level of performance.

This investigation represents a rigorous attempt to discover a "method" of training the human to recognize auditory patterns in an expeditious fashion. Specifically, the enhancement of learning this type of skill was the objective of several experiments. In general, no significant differences were found among groups of subjects trained under several methods. All groups attained fairly high levels of recognition skill with no apparent or compelling advantage for any one training method.

The implications to be derived from this study are that the development of an improved training device to teach sonar recognition skills must await the development of a more complete understanding of the recognition process. (This report should be a valuable guide to future work in this area in that it shows many of the more conventional approaches to aiding learning of this nature do not make much difference and may be inappropriate.)

This exhaustive effort has treated only the acquisition problem of the auditory pattern recognition skill in sonar-like tasks. Further work will be required to assess the value of training methods in this area in terms of longer term retention. Finally, before recommendations for device development are clear, there must be some demonstration of the transfer of the human's learning in the synthetic recognition situation to a variety of operational settings.

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SECTION I

INTRODUCTION

Despite recent advances in engineering and cybernetics the human operator is still superior to automatic systems in the ability to recognise complex patterns. The passive sonar operator, although aided by highly sophisticated equipment still has to make important judgments concerning the nature and origin of the sounds he hears, one of his main objectives being to classify the sound source as, for example, a submarine or a cargo ship. This investigation is not concerned with any actual sonar system but with the general problem of classifying very complex auditory inputs and in particular how auditory recognition skills are acquired. Similar problems occur in vision, for example, aircraft recognition, and probably in many industrial tasks especially those involving inspection and fault finding.

Perceptual learning has, until recently, received rather less attention than the acquisition of motor skills and verbal responses. Hebb (1949) raised the general question of if and in what manner we learn to perceive and E. J. Gibson (1953) reviewed work on the effects of training on perceptual efficiency. Experience with realistic or "live" material seems particularly important. Gibson had shown how sheer experience with the material can result in improved accuracy of judgment and in sonar Mackie and Harabedian (1964) found greater transfer value from more realistic (often noisy) materials. Wallis (1963) drew attention to the perceptual nature of many of the changes which occur during the acquisition of skill and attempted a survey of the conditions under which perceptual learning occurs. He stressed demonstration of the relevant cues embedded in the complex whole by such methods as drawing attention to one cue at a time and using materials in which such cues are presented "prominently". Trainees may even be required to acknowledge which cues they are using explicitly but as practice proceeds this analytic approach should be gradually relinquished such that the perceptual judgments become more immediate and less consciously analytic. As in most other forms of training knowledge of results is said to have an important role in correcting "misperceptions". Overall the process of learning to identify complex patterns is seen by Wallis as a blend of analytic and synthetic processes. Initially the complex stimuli are approached analytically by attention to cues and features but these must eventually be synthesised in a whole, more or less immediate, identification, just as a learner might at first laboriously classify a plant by reference to the shape of its leaves the distribution of petals etc. but the experienced botanist immediately recognises a rose as a rose.

Allan (1957, 1958) contrasts analytic with synthetic training methods in aircraft recognition. The classic WEFT method (wings, engine, fuselage and tail) especially emphasises systematic practice in recognising defining features in a quite explicit manner. On the

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other hand, Renshaw's flash system in which 'whole' sample stimuli are presented tachistoscopically especially emphasises recognition of total patterns ab initio. Gibson (1947) concluded that 'whole' methods were "slightly less efficient" than methods which emphasised feature analysis. Allan evaluated the Sargent system of aircraft recognition training which contains some aspects of feature recognition with emphasis on whole patterns. A few very clear key pictures are presented along with a booklet of 120 pictures of 4 aircraft types in various attitudes and at various distances. The trainee learns by sorting these into each of the 4 types referring to the standard key pictures. This method turned out to be more successful than the WEFT type training. Subjectively, Allan reports, "I was aware of knowing a shape without being able to describe or draw the details". It would seem that both the inspection of distinctive features and experience with the whole patterns are important elements in training.

This change from attention to features to more global characteristics as a function of training and experience also emerges from a study by Silver et al. (1965) of the cues used by radar operators at different levels of proficiency. "As proficiency increases there is a tendency to collapse simple judgmental dimensions into more complex continua: that is proficient controllers tend to judge similarity in terms of overall relational properties rather than simple stimulus attributes".

Work in auditory pattern recognition training (apart from speech perception) is contained in rather few studies. Swets (1962) and Swets et al. (1964) and also Sidley et al. (1965) have investigated the value of KR* in learning to identify meaningless complex sounds. The Swets studies revealed that a prompting or cueing technique was more effective than simple KR whilst Sidley et al. showed that KR could be more effective if there were some temporal overlap with the auditory signal. A series of studies by the present author (Annett (1966), Annett and Clarkson (1964), Annett and Paterson (1966, 1967)) generally confirmed the equivalence of KR and cueing in learning auditory detection and discrimination skills.

Mackie and Harabedian (1964) investigated the effects of realism in sonar training materials finding the greatest transfer to the operational task from the highest degree of realism, that is, using 'noisy' sea-recorded sounds rather than simplified synthetic stimuli.

Corcoran et al. (1968) conducted a set of experiments with the aim of establishing which of the many possible variables are important in training for passive sonar classification. Specifically they enquired into the type of verbal instruction which should accompany auditory training, whether any advantage is to be gained by a systematic ordering of sample sounds, whether training items should be easy or

* Knowledge of Results

difficult, whether KR or cueing is preferable and the extent to which generalisation occurs from training materials to a wider range of sounds. Using synthetic sonar-like sounds eight training conditions were compared. In brief, some difficulties were found to be associated with the verbal labels applied by instructors to the sounds the trainees were learning. These were only helpful if they successfully conveyed to the trainee the actual parameters of the sounds to which response must be made. Systematic ordering, consisting of changing only one stimulus characteristic at a time when moving from one sound item to the next was found more effective than random order presentation. Progressively increasing the difficulty of items showed no advantage but alternating noise-free with noisy recordings did. KR was slightly but not significantly superior to cueing and transfer and generalisation were demonstrated from the training materials used.

From this brief review it is clear that rather more research into the processes of learning to identify complex auditory patterns is desirable. Some of the main points are as follows:

(1) A fully developed recognition skill seems to involve enhanced perception of the whole characteristics of a complex stimulus whilst at the earlier stages recognition is more analytic in the sense of relying on the isolation of distinctive features or cues but there remains some doubt as to whether "whole" or "analytic" methods get the best results overall.

(2) The relationship between the stimulus and how it is described is somewhat idiosyncratic and the expert's description is not necessarily meaningful to the novice. Instruction seems an obvious way of drawing attention to defining features yet an over intellectualised approach seems incompatible with the "immediacy" of successful pattern recognition.

(3) On the whole "realistic" materials are preferable but judicious use of some noise-free samples may be of some advantage, possibly by teaching the trainee to attend to relevant features or cues.

(4) KR and prompting or cueing are probably equivalent. Probably the only essential requirement is that the trainee shall know the "name" of the sound he is hearing or has just heard.

(5) There may be some advantage in non-random ordering of samples. Again this may relate to methods of attending to defining features and cues.

The sum total of unambiguous information on the problem is by no means impressive and the process by which recognition skills are achieved remains rather mysterious. The present investigation attempts to look further into some of these issues, in particular the problem of how attention to limited aspects of the total complex stimulus may aid recognition, the role which verbal instruction may play, and some more possibilities of non-random ordering of materials. The question of KR vs. cueing is regarded as settled and the recommendation that realism is desirable is essentially undisputed.

SECTION II

PLAN OF THE INVESTIGATION

Part and Whole Methods

The preceding review indicates that some form of part training which draws attention to features of complex stimuli would be advantageous, at least in the early stages. This study is concerned with two contrasting approaches to part training; the first is called part-synthetic and the second, part-analytic.

Part-synthetic represents a conventional approach to the problem. Training begins by teaching the subject to make accurate judgments about cues isolated from the rest of the total sound complex. In passive sonar the most obvious breakdown is by source of the sounds, for example, propeller cavitation, engine noise, various other noises such as those caused by machinery on board, shaft squeal and so on. The part-synthetic method is progressive, building up the whole sound from its previously learned constituent parts. Discriminable cues are added to the total sound as the trainee becomes proficient in using them and finally he learns to arrive at a classification of the whole sound on the basis of all relevant cues. The part-synthetic method is virtually the auditory equivalent of the WEFT aircraft recognition system.

The part-analytic method, by contrast attempts to draw attention to features whilst retaining the context of the whole sound. This is achieved by taking "whole" sound samples and, for a short period, attenuating unwanted features. For example, for part of the listening period the trainee hears a "whole" warship and then the sound of the propeller only, followed by the whole sound again. Since the major difficulty with most part training methodsis how to recombine the parts successfully the part-analytic methods might facilitate transfer to the final test situation.

Whole Methods. In the present context "whole" methods constitute any form of training in which subjects are exposed only to complete complex sounds. Training method can vary considerably in other important respects such as the type of verbal instruction, order in which sound samples are presented and so on.

The Role of Verbal Instruction

Verbal instruction could be useful to the trainee in at least two ways. Firstly verbal descriptions, provided they were appropriate to the auditory material, might be used to identify relevant features or cues. If the subject performs his own analysis of a complex sound an appropriate set of verbal labels might help to focus attention on, for example, the rhythmic character of cavitation sound or an almost

masked propeller shaft squeal. Secondly verbal instructions might be used to help the trainee make appropriate classification judgements by drawing attention to the "cue value" of various characteristics. For example it could be helpful to know that echo-ranging is (for the purposes of this experiment) only associated with warships and submarines. Providing the subject is capable of learning various relevant characteristics, a verbal scheme, listing the characteristics of each type of 'target' could be an explicit aid to classification.

Installation of both types and of varying degrees of detail were used in these experiments.

Ordering of Training Items

The order imposed on a set of training materials is partly determined by other features of the training method. For example, the part-synthetic method implies a progression such that training on one characteristic, such as propellers, is completed in a batch of trials before training on the next, for instance engines, is begun. But sound samples can be ordered not only by relevant features but by target classification. For instance in the "whole" methods alternating samples of warships and submarines can be used to sharpen up the discrimination.

The baseline conditions presented sound samples in random order, but depending on whether the whole, part-synthetic or part-analytic method was being used the effects of introducing various non-random orders were investigated.

Choice of Methods for Comparison

A very large number of possible training methods would result from systematic combinations of whole and part with different types and levels of instruction and different orderings of training materials but at least some combinations are not practical propositions. For this reason a conventional systematic design involving the three main variables at several levels was not really appropriate and only those combinations which constitute a practical teaching method were used.

Training research is aimed at finding a "best method" but there is a risk that statistically significant results can be obtained by using a weak control, for example, the standard lecture versus a programmed text. In order to minimise this danger, three preliminary experiments were carried out on variations of each of the three main methods (Whole, Part-Synthetic, Part-Analytic). In each of these pilot experiments, designated P1, P2, and P3, several versions of the above methods were compared in order to establish a feasible and non-trivial version for later comparison in the main experiment.

In the three pilot and one main experiment a total of 15 different training methods were employed. These are described in detail in section IV but first the physical arrangements for producing training and test material are described.

SECTION III

APPARATUS AND THE PREPARATION OF STIMULUS MATERIAL

Apparatus

All sounds used in these experiments were synthesised in the laboratory by electronic and mechanical methods described below. The aim was to produce realistically complex sounds with the same general characteristics as passive sonar but without any serious attempt to simulate actual ships or to emulate the features of any one sonar system.

The part-synthetic and part-analytic methods required the use of sounds which could be decomposed into propeller, engine and other sounds. These were synthesised separately and stored on eight track tape on a VR-2800 recorder from which they could be played back separately or in any desired combination. For some experiments signals were fed to subjects direct from the VR-2800 whilst in others, where access to component sounds was not required, the sounds were transferred to a more convenient mono-track tape.

Preparation of Stimulus Material

Propeller Cavitation

The output of a Dawes white noise generator was passed through an octave band filter into a two stage transistorised amplifier. The gain of the amplifier was modulated at various rates by a device consisting of a perspex disc with four splashes of black paint representing propeller blades, a light source on one side and a photo-cell on the other and the disc rotated by a variable speed motor. The octave band filter was centred on 500 Hz for cargo ships, 1000 Hz for warships, 200 Hz for submarines and 4000 Hz for lightcraft.

The filtered noise was modulated at rates between 60 and 100 r.p.m. for cargo ships, 100-200 r.p.m. for submarines, 200-300 r.p.m. for warships and 300-450 r.p.m. for lightcraft to represent appropriate cavitation rates.

Asynchronicity in multiple propellers was simulated by super-imposing two sounds of the same pitch modulated at slightly different frequencies.

Engine Sounds

These were obtained mixing sine waves, square waves and ramps with a purpose-built ring modulator and then filtered to produce a variety of whines, buzzes, roars and rumbles, some pulsed and some continuous and some rhythmic. The predominant pitch of warships and cargo ships was

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low (warships being on average higher) and submarines and lightcraft higher still. Lightcraft engines were predominantly pulsed whilst submarine engines were more continuous and rhythmic.

Shaft Squeal and Hull Resonance

Both these sounds were produced in conjunction with the apparatus for producing propeller cavitation and so synchronised with shaft rotation. A short, high pulse (1000-2000 Hz) was used for squeal and a longer lower pulse (200-300 Hz) for resonance.

Sonar

Echo-ranging type sounds were made by regular pulsing of the output of an 800 Hz oscillator.

Other Mechanical Ship Sounds

Irregular sounds representing the movement of cargo and on-board machinery were made by hitting a central heating radiator, recording at $7\frac{1}{2}$ inches per second and replaying at $1\frac{7}{8}$ inches per second. Flapper valves associated with snorkelling submarines were produced by the method suggested by Mackie and Harabedian. A hammer, held lightly, was allowed to strike and bounce on a radiator thus producing a damped wave-train of clanks.

Sea Noise

White noise passed through a variety of filters.

Biological Sounds

"Shrimps" were simulated by drawing a wire brush slowly across the face plate of a microphone and playing back the resulting crackling sound at half speed. "Porpoise" sounds were produced by rapidly twisting the dials of a medium frequency signal generator and over-driving the input to the tape recorder. "Whale" sounds were low grunts and groans produced by playing a human voice recorded at $7\frac{1}{2}$ inches per second backwards at 15/16th inches per second (the effect is impressive if totally unrealistic). "Carpenter fish" sounds were produced by driving a loudspeaker in a resonant chamber by pulses from a multi-vibrator.

These sounds were transferred to separate tracks on a VR-2800 multi-track recorder in various combinations to create a library of 120 ships, thirty in each of the four categories. Full specifications

of each sound are available on request.

It can be seen that there was no overlap between categories as regards propeller cavitation. Either the pitch or the cavitation rate could, if correctly estimated, identify the ship. Engine sounds, on the other hand, overlap considerably, particularly those of warships and cargo ships. Some sounds such as echo-ranging and flapper valves are specific to certain ship types but are not always present.

Finally each complex sound contains the irrelevant components of sea noise and often biological noises. Further details of the distribution of sounds amongst the ship types can be seen in the "cue classification chart" shown in Appendix (H) used as part of the training materials in some conditions.

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SECTION IV

TRAINING METHODS

Random Order - No Instructions - Method 1.

This was the baseline condition. Subjects were instructed that they would hear unfamiliar sounds resembling those made by ships heard through underwater listening equipment, that these would be four types, warships, cargo, submarine and lightcraft and that their task was to learn to discriminate between these types. In each session subjects had a proforma (Appendix (A)) showing 4 columns of 20 items, alternate columns being correctly labelled or blank. Each item was presented for 15 seconds with a 10 second blank between items during which, in the test trials, the subjects placed W, C, S or LC against the stimulus number. Between runs of 20 the interval was 15 seconds. One session lasted under one hour and in the pilot experiment there were three such sessions and in the main experiment five sessions.

Random Order - With Instructions - Method 2.

The stimulus material and training/testing regime was as for Method 1 but subjects were given a sheet of "extra" instructions (see Appendix (B)) which summarised the features of the sound sources, such as propellers, and also summarised the sounds characteristic of the four ship types. In addition to these instructions there was a further sheet (Appendix (C)) which gave a detailed breakdown of the component sounds of each of the training items. Subjects were instructed to look at these whilst listening to the items and to try to make use of these cues in classification on the test trials.

Ordered - No Instructions - Method 3.

This condition differed from Method 1 insofar as the training items were presented in alternating pairs. Thus over 3 sessions (6 sets of training items) the stimuli were presented W/LC, C/S; W/C, LC/S; L/C, W/S. This means that each type of ship was heard with equal frequency in each of the 3 sessions. In session 1 after the first 20 items (warships alternating with lightcraft) there was a 10 item test of these two types in random order. Then followed 20 cargo and submarine items with a 10 item test and finally a 20 item test with all four types in random order (Appendix (D)). The same procedure was used for the second and third sessions using W/L, LC/W and L/C, W/S, respectively.

Ordered - With Instructions - Method 4.

Same as for Method 3 but with instructions of the same type as given in Condition 2 (Appendix (E)).

Ordered Groups - No Instructions - Method 5.

Due to the problem of accessing items on the library tape in experiment P3 (part-analytic) it was necessary to present items in sets of 5 of the same type. This condition was the same as Method 1 except for the grouping of items on training trials. Test trials consisted of the standard sets of 20 randomly ordered items.

Random Order with additional practice on difficult items - Method 6.

Warships and submarines proved to be the items most easily confused with each other. This was the same as Method 1 except that each training trial of 20 items contained 7 warships and 7 submarines with 3 cargo and 3 lightcraft instead of 5 of each type (Appendix (F)).

Part-Synthetic Methods

Methods 7, 8 and 9.

These methods can best be described in terms of seven stages which attempt to build up identification skills by first teaching recognition of component sounds. Methods 7, 8 and 9 consist of different combinations of these seven stages.

Stage 1

Subjects were played one whole sound (a warship) which was then broken down into its parts, propeller, engine, sonar and other ship sounds, background noises and sea noise, all heard in isolation. Subjects were then taught to identify propeller, engine, other ship sounds, biological and sea noise, each heard in isolation. A 12 item test established that subjects could correctly identify these components in isolation.

Stage 2

In the second stage subjects were taught, by the use of labelled examples, to distinguish between different cavitation rates, pitch and the presence or absence of propeller asynchronicity. On 12 propeller samples each characteristic was demonstrated in turn and in a further 12 samples all three characteristics were demonstrated for each item. This was followed by a 12 item test in which subjects were required to make the appropriate judgments of cavitation rate, pitch and synchronicity.

This procedure was repeated for the discrimination of engine characteristics, such as pitch, whether pulsed or continuous and whether rhythmic or non-rhythmic and again these discriminations were tested. The identification of other ship sounds and of biological sounds was then treated in the same way.

Up to this stage and with the exception of the first "whole sound" item in Stage 1 all the components (propellers, etc.) were heard in isolation in both training and test items and no mention made of different ship types or the use of these cues in classifying sounds.

Stage 3.

The next step was to repeat the testing of Stage 2 with whole sounds. For example, subjects were required to make judgments of propeller cavitation rate, pitch and synchronicity in items consisting of propeller, engine and all the other sounds including sea noise. The tests were repeated for engines, other ship sounds and biological noises.

Stage 4.

Subjects were provided with a combined cue checklist (see Appendix (G)). The list contained 20 items with a column for each feature that subjects had been taught to distinguish, e.g. propeller cavitation rate, pitch, etc. Subjects listened to the 20 items. For the first 10 the checklist was correctly completed whilst subjects had to complete the checklist for the second 10 items unaided.

Stage 5.

Up to this stage subjects could, with a fair degree of accuracy, distinguish all the relevant cues in an item but know nothing of how to use these cues to classify an item as belonging to any of the four categories of ship. Stage 5 taught classification as a separate exercise on paper without listening to sound samples. Subjects were given a set of instructions; the classification cue chart (Appendix (H)) described how the cues they had been taught to identify could be used to classify whole sounds into the four ship types. They were also given a checklist (Appendix (I)) showing 10 ships with all characteristics correctly checked off and the type of ship correctly idmntified and were required to work through this.

Stage 6.

Stage 6 consisted of a further classification exercise of 10 training and 10 test items but with subjects listening to the actual sounds referred to on the paper checklist. Subjects were required to check off the components and to classify the whole sound.

Stage 7.

The final test was identical to the final test in other conditions, that is 20 randomly ordered items to be classified in the usual manner without the aid of the checklist.

Conditions 7, 8 and 9 (experiment P2) differed only in the number of stages employed. Method 7 consisted of Stages 1, 2, 3, 5 and 7; Method 8 of Stages 1, 2, 3, 4, 5 and 7; and Method 9 of Stages 1, 2, 3, 5, 6 and 7.

In all these conditions the training and testing was divided between three sessions of approximately one hour's duration on 3 successive days.

Limited Synthetic - Method 10.

In Methods 7, 8 and 9 the attempt was made to teach subjects about all the cues we had built into the sound samples. Not only was this a formidable list but some of the cues were of rather dubious value in classification. Strictly speaking it should be possible to distinguish the 4 categories on the basis of propeller

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cavitation rate alone or even propeller pitch alone. The Limited Synthetic method taught only propeller sounds in isolation and was extended over 5 sessions of approximately one hour's duration.

Training began with 20 training and 20 test items as in Method 1, the test items serving as the "pre-test". Next came Stage 1 of the synthetic methods designed to demonstrate how the complex sounds broke down into components and to teach recognition of these components. Training then concentrated entirely on propellers referring only to cavitation rate and pitch. There were 20 cued training items followed by 20 uncued test items. Next 20 training and 20 test items were given with whole sounds, subjects still being required only to learn propeller cavitation rate and pitch.

On the next session subjects were provided with a simplified classification cue chart (Appendix (J)) which showed how the four ship types could be identified by correct judgments of propeller cavitation rate and pitch and they were given 12 practice and 20 test items. Further training sessions were then given on discriminating propeller characteristics both in isolation and in the context of whole sounds and this followed by further sessions with the limited classification cue chart using whole sounds and then training was extended over 5 one-hour sessions ending with the standard 20 items classification test without the aid of the checklist.

Full Synthetic - Method 11.

This condition was an extended version of Methods 7, 8 and 9 extended over 5 sessions but using a rather more restricted set of cues. (See classification cue chart, Appendix (K)). Like Method 10 it began with 20 random training and 20 random test items (whole sounds) and then proceeded to Stage 1 demonstrating the breakdown of the whole sound into its components.

Next, discriminations of propeller cavitation rate and pitch, engine pitch and the other sounds were taught using each component in isolation. There were 20 training and 20 test items for propellers, 10 training and 10 test for engines and 10 training and 10 test items for other sounds (mechanical and biological). In the next session the same training was repeated with whole sounds. In the next session classification was taught by a paper exercise involving the reduced classification cue chart (Appendix (K)) and 30 training and test items (Appendix (L)). The first 10 items were fully cued. In the next 10 the components were correctly identified but subjects had to arrive at their own classification. In

the final 10, some characteristics were misidentified, that is to say the evidence was conflicting. Then followed a 20 item training and test session listening to sound items. The first 10 were fully cued and the second ten uncued. In the fifth session this training was continued with 20 training and 20 test items and this was followed by 20 training items of the conventional kind (i.e. only final classification was given) and then the standard 20 item test.

Part-Analytic Methods

Part Sound, Analytic, Controlled Access - Method 12.

The part sound analytic methods made use of the facility provided by the VR-2800 recorder in which whole items could be played or by the use of switches either the subject or the experimenter could accentuate one channel by 4-6db for example, propeller or engine sounds, and attenuate all others by about 2db. The aim was to point out useful cues whilst preserving the context of the whole sounds. The structure of the part-analytic methods resembled that of the whole methods in so far as it did not have the progressive stages of the synthetic methods, thus sessions consisted of two sets of 20 training and 20 test items with the access facilities available on the 20 training items only. Since only one VR-2800 was available the actual library tape had to be used and the items on this tape were in groups of warships, submarines, etc. It was not possible to access any of the 120 items at high speed in a random order so samples were given in groups of 5 of the same type, e.g. 5 warships. Items were of 15 seconds duration.

In the controlled access method the middle 5 seconds of each item consisted of accentuating one channel and attenuating the others. The grouping into sets of 5 enabled subjects to hear the propellers, engines, other ship sounds, etc. for a set of 5 items of the same ship type. As before, training consisted of cueing, that is telling the subjects to what they were listening. Since propellers and engines contributed the most important cues these were accentuated more frequently than unimportant cues and irrelevant sounds. Propellers, engines, etc. were accentuated in groups of 20.

This method was used in the pilot experiment (P3) in three sessions and in the main experiment for 5 sessions, where there were 60 propellers, 60 engines and 40 other sounds such as sonar and flapper valves, 20 training trials alternated with 20 test trials throughout.

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Free Access - Method 13.

Subjects were provided with a set of labelled switches which enabled them to accentuate any of the channels at will rather than for the middle five seconds only. An event recorder provided a permanent record of how much time was spent listening to each channel. 20 training trials alternated with 20 test trials throughout.

Free Access, extra instructions - Method 14.

This was identical to Method 13 except that subjects were given a sheet of instructions indicating the relevance and reliability of the different cues for classification programmes (Appendix (M)).

Controlled Access, extra instructions - Method 15.

This was identical to Method 12 but extra instructions were provided similar to those given in Method 14 (Appendix (M)). This method was run for 3 sessions in the pilot experiment and 5 sessions in the main experiment.

SECTION V

THE PILOT EXPERIMENTS

Subjects

Subjects were recruited from various local sources, high school and university students of both sexes and members of a rugby club and their wives and girlfriends. They were paid 7/6d. per hour. All were given a brief audiometric check and some volunteers were rejected and advised to visit their doctors for a more thorough examination. Experiment P1 used 36 subjects, P2, 26 and P3, 20 subjects, all university students.

Whole Sound Methods - Experiment P1

This experiment compared Methods 1, 2, 3 and 4 over three training sessions, each comprising a total of 40 training and 40 test sounds including 20 samples of each of the four ship types. Corcoran et. al. changed one relevant characteristic at a time and concluded that "sounds which the trainee is likely to find difficult to distinguish should be presented alternately", not separated in time or by other sounds. If correct identification involves making comparisons, alternating pairs should show some advantage over random presentation.

Therefore HYPOTHESIS 1 is that some ordered presentation is superior to random presentation.

Corcoran et. al. also found significant effects due to the type of verbal instruction given. Although their results only concerned the aptness of the verbal label to the sound, common-sense suggests that instructions drawing attention to features which form useful classification cues would be effective.

HYPOTHESIS 2 is that instructions are superior to no-instructions.

Each session included two 20-item tests in which subjects were required to classify each item as warship, cargo ship, submarine or lightcraft. The main results were in terms of the number of correctly identified test items but inter-item confusions were also examined.

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Results

Table 1 shows the mean number of items correctly identified on tests 2, 4, and 6 (the second test on each of the 3 daily sessions). A two-way analysis of variance (Table 2) shows that the average improvement (from about 50% to about 70%) is highly significant. However, there were no

TABLE 1. EXPERIMENT P1. MEAN NUMBER OF CORRECT RESPONSES (MAX = 20) ON THE SECOND TEST OF EACH DAILY SESSION

	Method 1 (RNI)	Method 2 (RWI)	Method 3 (ONI)	Method 4 (OWI)
Day 1	7.33	10.67	10.11	9.33
Day 2	9.44	10.0	10.22	9.11
Day 3	13.33	13.78	13.67	13.78

TABLE 2. EXPERIMENT P1. 2-WAY ANALYSIS OF VARIANCE ON TEST SCORES FOR FOUR METHODS ON THREE SUCCESSIVE TESTS

Source	ss	df	MS	F	P
Between S's	445.2130	35			
Methods	34.99075	3	11.66358	.9098352	NS
Subjects within groups	410.2222	32	12.81944		
Within Subjects	776.6667	72			
Days	401.6296	2	203.8148	35.54148	$p < .001$
Methods X Days	30.59258	6	5.098764	.9641786	NS
Between S's within Groups	338.4444	64	5.288194		

significant differences between groups, that is, Methods 1 to 4. The pattern on tests 1, 3, and 5 is, however, different and does indicate an advantage in favour of instructions, but since the final test 6 shows no difference this must be treated with caution. Since each of the items was used many times in the course of the experiments it was possible to estimate the difficulty of each. A detailed examination suggested that items in test 5 were rather less difficult than items in test 6, throwing some doubt on the suggestion of overall better performance of the conditions with instructions. The result of the pilot experiment was, therefore, that differences between conditions could not be definitely demonstrated. There was just a hint that the instructions may have been of some help but that this may be confined to the early stages of practice. Thus hypotheses 1 and 2 were not supported.

Experiment P1 did, however, demonstrate that subjects could be taught to identify complex sounds and that exposure to labelled samples was possibly the most significant factor contribution to learning. A systematic ordering of training items had little discernible effect.

Part-Synthetic Methods - Experiment P2

Experiment P2 was carried out largely to establish a feasible technique for part-synthetic training. Three versions, Methods 7, 8, and 9 were compared in this experiment. Method 8 differed from Method 7 by providing an additional opportunity (stage 4) to practise making judgments of complex sounds. Method 9 differed from Method 7 by having an additional classification exercise listening to whole sounds.

HYPOTHESIS 3 was that both these additions would show some advantage over the "minimum" Method 7.

HYPOTHESIS 4 was that all three would be superior to Method 1 random order, no instructions.

Each stage of the part-synthetic procedure was followed by a short test to ascertain that subjects had mastered the relatively simple discrimination at each stage. Only in the final test can the conditions be compared with each other and with results obtained in the other pilot experiments.

Results

Table 3 shows the results of all the subjects for Methods 7, 8, and 9. Note that at each stage quite high levels of performance were achieved. For example, on test 2.A the discrimination of propeller cavitation heard in isolation varied between 87% and 94% and this dropped only a little on test 6 where the same discriminations were made but in response to whole sounds. Engines were rather more difficult to discriminate. The "paper classification exercise" also gave high levels of performance. Clearly subjects could learn to identify the components of complex sounds using

TABLE 3. EXPERIMENT P2 TEST RESULTS OF THREE GROUPS OF SUBJECTS, COMPARING THREE PART-SYNTHETIC METHODS

Test		Methods 7	Methods 8	Methods 9
		%	%	%
1.	Discrimination between sound components	82.5	96.92	87.5
2.	Propeller characteristics (in isolation)	87.40	86.20	89.58
2.A	Propeller characteristics (in isolation)	94.17	87.64	91.93
3.	Engine characteristics (in isolation)	70.42	71.01	73.79
3.A	Engine characteristics (in isolation)	70.97	69.97	71.18
4.	Identification of "other ship sounds"	85.83	89.58	79.17
5.	Identification of biological and sea sounds	86.67	92.75	84.17
6.	Propeller characteristics in whole sounds	80.10	83.59	80.47
7.	Engine characteristics in whole sounds	73.06	69.79	72.57
8.	Other ship and biological in whole sounds	63.04	64.13	68.48
PE.	Paper characteristics exercise	90.50	86.90	87.50
9.	Cue checklist, all components		50.66	53.01
9.A	Classification with checklist			52.50
F	Criterion Classification Test	51.00	48.75	50.65
N =		10	8	8

the checklist. However, in tests 9, 9.A and the final test, performance drops sharply to about 50% indicating the difficulty experienced by subjects in putting together the auditory discriminations and the decision-making elements of the task. The groups were compared in the final test by a one-way analysis of variance (Table 4) but were not significantly different and so hypotheses 3 and 4 were not accepted.

TABLE 4. EXPERIMENT P2 ONE-WAY ANALYSIS OF VARIANCE ON FINAL TEST SCORES

Source	ss	df	MS	F	P
Methods	0.9865417	2	.4932709	.0567332	NS
Error	199.9750	23	8.694566		
Total	200.9615	25			

Part-Analytic Methods - Experiment P3

This experiment compared Methods 5, 12, 13, and 14 and was again primarily exploratory but based on the general hypothesis that part methods would be superior to whole methods and that part-analytic would show some advantage over part-synthetic by combining experience of whole sounds with the opportunity to attend to significant parts.

HYPOTHESIS 5 was that Methods 12 and 13 are superior to Method 5.

HYPOTHESIS 6 Method 14 is superior to Method 13.

Furthermore, in accordance with the hope that instructions on the value of cues in classification would be beneficial it was predicted that Method 14 would be superior to Method 13.

Results

As in Experiment P1 there were 6 20-item tests and group mean scores are shown in Table 5. A two-way analysis of variance (Table 6) showed highly significant improvement with practice. The improvement was comparable with that achieved in Experiment P1 although the range was a little greater from just under 50% in test 2 to about 70% in test 6. Although Method 14 which gave extra instructions came out best, differences overall were insignificant and hypotheses 5 and 6 could not be accepted.

TABLE 5. EXPERIMENT P3 MEAN OF CORRECT RESPONSES (MAX = 20) ON SIX SUCCESSIVE TESTS

Method	5 (No Access)	12 (Controlled Access)	13 (Free Access)	14 (Free Access Extra Instructions)
Test 1	7.8	7.2	6.8	9.4
2	8.8	8.6	7.6	9.6
3	8.0	10.2	10.6	11.0
4	11.2	10.0	9.2	12.4
5	11.4	10.6	11.2	11.0
6	13.0	14.6	12.6	15.4
N =	5	5	5	5

TABLE 6. EXPERIMENT P3 TWO-WAY ANALYSIS OF VARIANCE ON TEST SCORES FOR FOUR METHODS ON SIX SUCCESSIVE TESTS

Source	ss	df	MS	F	P
Between S's	362.4917	19			
Methods	55.09170	3	18.3639	.9558308	
Subjects within Groups	307.40	16	19.2125		
Within Subjects	974.5	100			
Trials	455.3417	5	91.06834	15.83109	.01
Methods X Trials	58.95831	15	3.930554	.6832775	NS
Between Subjects within Groups	460.2	80	5.7525		

Conclusions from the Pilot Experiments

The internal comparisons within each of the three pilot experiments proved insignificant. However, the whole methods and the part-analytic methods would appear more successful than the part-synthetic methods.

Unfortunately P2, by reason of the progressive nature of the part-synthetic methods did not include a pretest and comparisons were only possible on the posttest. The mean number of sounds correctly classified in the combined group in P1 (Whole) was 13.64, in P2 (Synthetic) was 10.04 and in P3 (Analytic) was 13.9 (Maximum = 20 in each case). A one-way analysis of variance (Table 7) showed this difference to be highly significant. With the absence of a pretest control this difference could not be attributed definitely to difference in method but since there was no reason to suspect that the subjects in P2 were any worse than P1 and P3 the conclusion that the synthetic method was poorer has some justification as a basis for attempting to devise more effective synthetic methods.

TABLE 7. EXPERIMENTS P1, P2, AND P3 ONE-WAY ANALYSIS OF VARIANCE ON POSTTEST SCORES

Source	ss	df	MS	F	P
Treatments*	243.1281	2	121.5640	16.64202	$p < .001$
Error	577.0670	79	7.304646		
Total	820.1951	81			

* The three "treatments" are whole, part-synthetic and part-analytic, sub-conditions being combined for the purpose of this analysis

In P1 no effect of ordered presentation could be detected but there was a slight suggestion that instructions had helped. In P2 the attempt to build up the classification skill in stages was almost a complete failure. In practical terms the training time (which was approximately the same for all 3 experiments) could have been better spent presenting large numbers of correctly labelled "whole" items. The difficulty seems to relate to the combination of the separate skills of identifying cues and drawing conclusions from the evidence. Both were attained satisfactorily but could not be readily combined, despite attempts in two of the three conditions to aid this process. The question therefore arose that maybe synthetic methods would be more effective in the longer terms with more consolidation of the components and more practice in combining them.

The results of P3 (Part-Analytic) seem to suggest that the isolation of elements gives no advantage over the training regime of P1 which it closely resembled in other respects. As in P1 the data suggest that instructions may be of some assistance and possibly only the small size of the groups and the relatively short duration of training prevented these effects from showing up as statistically significant. With these points in mind the main experiment was planned.

SECTION VI

THE MAIN EXPERIMENT

Conditions

Two variations on each of the three main methods were selected for comparison in the main experiment. Representing the whole methods were Method 1, random order, no instructions, to provide a baseline of minimal training sophistication, and Method 6 in which additional samples of the most difficult categories were given. Since synthetic methods (7, 8 and 9) appeared to be markedly less effective two new synthetic methods, 10 and 11, were devised. The pilot experiment showed striking differences in performance between isolated judgments (Table 3, tests 6, 7 and 8) and tests requiring the combination of judgments into classification (tests 9, 9a and 10). This suggests that the classic difficulty of part training, the combination of previously learned subskills, is at the root of the trouble. Method 10 was an attempt to deal with this by giving extensive pre-training on two highly reliable cues, propeller cavitation rate and pitch and ignoring other relevant but less helpful cues (such as flapper valves, sonar, etc.) Method 11 (full synthetic) included training on <u>all</u> relevant cues.

Representing the part-analytic methods was Method 12, (controlled access) which was used in P3 and a new Method 15 in which additional instructions regarding the cue value of isolated characteristics of the sound were provided. In the pilot experiment the data suggested that such instructions would be of some value.

Finally the main experiment involved more subjects in each group and training was extended from three sessions to five. In addition, all groups, including 10 and 11 (synthetic) were given standard pre-tests.

The following specific hypotheses concerning variations using the methods were tested.

<u>HYPOTHESIS 7</u>: additional practice on the more confusable items will be beneficial, therefore Method 6 will be superior to Method 1.

<u>HYPOTHESIS 8</u>: the combination of learned discriminations into a single complex judgment appeared to be the main reason for failure in synthetic methods, therefore pre-training on a limited range of relevant and reliable cues Method 10 will be superior to Method 11.

<u>HYPOTHESIS 9</u>: that part-analytic training which systematically draws attention to value of cues for classification will be superior to similar training without such instructions, that is Method 15 will be superior to Method 12.

HYPOTHESIS 10: finally, there is the general null hypothesis that none of these methods is superior to Method 1, whole sound, random order, no instructions.

Subjects

Subjects were recruited from university and high school students and members of a rugby football club - all young adults and initially naive to the task. They were subjected to audiometric screening. For various practical reasons relating to availability of both the subjects and the test equipment a completely random allocation of subjects to groups was not possible. However, a statistical check (described in the results section) allays fears that these groups might be subject to bias. A total of 71 subjects were tested.

Results of Main Experiment

The data were first grouped by subject source and one way analyses of variance were carried out on pretest and posttest scores. Table 8 shows that there were no significant differences due to subject source so the subjects were treated as an homogeneous set.

TABLE 8. MAIN EXPERIMENT. ONE-WAY ANALYSES OF VARIANCE ON (A) PRETEST SCORES AND (B) POSTTEST SCORES BETWEEN SUBJECTS RECRUITED FROM THREE DIFFERENT SOURCES

Source	SS	df	MS	F	P
(A) Pretest					
Subject groups	275.3652	2	137.6826	.8303966	NS
Error	11274.63	68	165.8035		
Total	11550.00	70			
(B) Posttest					
Subject groups	791.9336	2	395.9668	1.8749	NS
Error	14361.16	68	211.1936		
Total	15153.10	70			

It is clear from the means (Table 9) that all methods resulted in substantial pretest and posttest gains.

TABLE 9. MAIN EXPERIMENT. MEAN NUMBER OF SOUNDS CORRECTLY CLASSIFIED ON THE POSTTRAINING TEST

	Whole		Part-Synthetic		Part-Analytic	
Method	1	6	10	11	12	15
Pre	7.9	7.6	8.4	8.0	7.2	9.2
Post	14.2	13.3	16.4	14.2	12.2	14.8
Adjusted Post	14.226	13.638	16.441	14.251	12.275	14.668
N =	10	12	14	13	12	10

An analysis of variance (Table 10) for all groups combined showed this to be highly significant. In short, all the methods worked.

TABLE 10. MAIN EXPERIMENT. ANALYSES OF VARIANCE ON POSTTEST SCORES

Source	ssyy	df	MS	F	P
Methods	3183.5	5	636.70	3.4556	<.01
Error	11976.0	65	184.25		
Total	15160	70			

Next an analysis of co-variance (Table 11) was carried out with pre-test results as the co-variate.

TABLE 11. MAIN EXPERIMENT. ANALYSES OF CO-VARIANCE ON POSTTEST SCORES

Source	ssxx	ssxy	ssyy	ssyy	df	MS	F	P
Methods	651.49	1012.4	3183.5	2782.3	5	556.45	3.0571	$<.025$
Error	10899.0	1887.6	11976.0	11649.0	64	182.02		
Total	11550.0	2900.0	15160.0	14432.0	69			

All pairs of (adjusted) posttest means were compared by Tukey's method and only one difference emerged as significant at the 5% level, namely that between Method 12 (part-analytic, controlled access, no instructions) and Method 10 (limited synthetic) 10 was the best of all Methods and 12 the least effective. Thus it appears that hypotheses 7, 8 and 9 were not supported.

In the whole Methods, 1 was slightly, but not significantly, better than 6 which gave extra practice on difficult items.

The limited synthetic, Method 10, was better than full synthetic, Method 11, but not significantly so. It is, however, worth noting that the clear superiority of whole methods over synthetic found in the pilot experiments has been eliminated. This may have been entirely due to the greater amount of training given but the trend for better results when pretraining is given on a limited number of cues does seem to be present. To this extent, only, the data provided limited support for hypothesis 8.

The extra instructions given in Method 15 produced a non-significant difference in the expected direction over Method 12. Thus although hypothesis 9 was not supported there was possibly a tendency for some beneficial effect of instructions drawing attention to the cue value of elements of the complex sounds.

Finally hypothesis 10, that no method is superior to Method 1, whole sound, random order, no instructions, was tested by Dunnett's method in which the adjusted means of each group are compared with the mean of Method 1. None of these differences was significant and the null hypothesis cannot be rejected.

Regressions were fairly small and adjusted y means differ little from unadjusted means. From the analysis of variance, differences between posttest scores were significant at $p<.01$.

SECTION VII

DISCUSSION AND CONCLUSIONS

That people can learn to identify previously meaningless complex sound patterns is beyond doubt but how they do so is still an open question. This series of experiments represents an attempt to throw some light on how this skill is achieved and so suggests which training techniques are likely to be most efficient. Broadly there seem to be two types of approach to both the theory and practice of pattern recognition, one emphasising wholes and one emphasising parts or features. The "whole" approach suggests that patterns are recognised by matching to a template. The template itself is built up by experience and is based on an accumulated store of impressions derived from a standard or set of standard examples. The Sargent method of aircraft recognition emphasising the inspection of many samples without any attempt at analysis is consistent with this approach. On the other hand, the recognition by the identification of specific features has its attractions as a theoretical position. A major problem of the template theory is its apparent rigidity. Any pattern recognition model must be capable of correctly classifying widely different versions of the standard as the same. For example, a single template to recognise letters, such as a battery of photocells, cannot cope with a letter which is rotated through a few degrees for the pattern will just not match the template, whereas a system which recognised angles, curves and straight lines (or any other set of "features") could, by combining evidence from different feature analysers, reach a "decision" about the likely identity of the stimulus despite a number of variations in specific features. Feature testing theories are currently popular (c.f. Neisser, 1967). In practical terms a training method such as the classic WEFT system of identifying aircraft by reference to the features of wings, engines, fuselage and tail is consistent with the feature testing approach. Feature testing is also intuitively plausible. In attempting to say how one recognises an object there is a natural tendency to refer to defining features to explain the act of recognition. This seems true of the early stage of learning to classify, say insects or flowers but is less true of well practised tasks, such as recognising the faces of one's friends.

The present set of experiments represents a fairly determined attempt to find some way in which feature testing could be applied to developing a practical method of teaching the identification of complex (sonar-like) sounds. Various kinds of part practice and instructions have been used to attempt to draw attention to defining features, such as propeller cavitation rate, although spontaneous analysis of complex sounds clearly does not arise easily and in practice overall impressions carry some weight. Fifteen different

training methods have been tried in this series of experiments and although these by no means exhaust all the possibilities the basic result is that simple whole methods prove to be as effective as any of those which attempt, in one way or another, to draw attention to identifying features of complex stimuli. The subjects behaved much as might be expected on a template matching theory. The most potent factor leading to improved performance was sheer experience of labelled samples of the four categories of sound to be identified. Both the best and the worst results were obtained from methods which attempted to emphasise features. These were Method 10 (limited synthetic), where subjects were trained to listen to one aspect of the total sound complex which gave a reliable cue to the identity of the ship, and Method 12 (analytic controlled access) which broke down the complex sound into its parts without giving explicit instructions about the cue significance of the parts.

One of the most striking findings of the series was that subjects who could distinguish features at quite a high level and, separately, could combine these into a judgment of identity (i.e. explicit feature testing at a conscious level) failed to combine these skills. It is true, however, that given rather more practice (Method 11) this difficulty was overcome. The result, however, was in no way superior to that achieved by the simple whole methods. Nevertheless the most successful method was the <u>limited synthetic</u> where subjects concentrated on just <u>one feature</u> of the complex whole which was a defining attribute.

It would be unwise to take these results as being any more than just "tending to support" a template theory for several reasons. One is that the "features" which were experimentally manipulated may not necessarily have been the "features" intuitively used by the subjects in identifying sounds. Secondly even if we were using the "right" features (in this sense) it could be said that these were simply inaccessible to conscious manipulation. There could be a feature testing mechanism using "features" which we have not identified in these experiments or the mechanism might not be susceptible to conscious effort. Be this as it may the practical training procedures which a feature testing theory seems to suggest do not appear to offer any advantage over whole sound training.

These results draw attention to certain problems which have been investigated by other workers. Whilst Corcoran et. al. found that some orders of presentation were better than others none of the quite plausible variations used have produced a striking effect. One cannot rely on intuition about order in this kind of material even if ordering is thought to be important in progressively developing subject matters such as are found in programmed mathematics courses. Secondly Corcoran et. al. found that not all

sets of verbal labels were equally helpful. The present results suggest that elaborate verbal explanations are not particularly helpful thus throwing doubt on what must be one of the most cherished illusions of instructors. If instructions are given they should be simple and, if possible, refer to the one best cue. Detailed instructions about a variety of cues cannot be dealt with adequately and may even depress overall performance.

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APPENDIX A

COMPLEX SOUNDS. TEST TAPE I. ANSWER TEST SHEET.

SUBJECT No. ________ Test No. 1 ________ DATE ________

INSTRUCTIONS: All sounds are classified as Warship (W), Cargoship (C), Submarine (S), and Light Craft (LC). A fresh item is presented every 25 seconds preceded by an item number. Follow the items on the test sheet and try not to lose your place. Check off the training items 1-20 and 41-60 as you hear them. Identify the test items 21-40 and 61-80 by writing W, C, S or LC against the item number. If you don't know you must guess. There will be a short pause after each 10th item to check that you have not lost your place.

Item No.	Class	Item No.	Class	Item No.	Class	Item No.	Class
1	W	21		41	C	61	
2	LC	22		42	S	62	
3	W	23		43	S	63	
4	S	24		44	LC	64	
5	C	25		45	S	65	
6	LC	26		46	LC	66	
7	LC	27		47	C	67	
8	S	28		48	S	68	
9	W	29		49	LC	69	
10	S	30		50	LC	70	
11	C	31		51	W	71	
12	S	32		52	C	72	
13	S	33		53	W	73	
14	LC	34		54	C	74	
15	W	35		55	W	75	
16	C	36		56	S	76	
17	C	37		57	W	77	
18	C	38		58	W	78	
19	LC	39		59	LC	79	
20	W	40		60	C	80	

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APPENDIX B

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EXTRA INSTRUCTIONS

The following are a selection of typical sounds made by four types of ship.

Each sound can have the following components:-

Propeller Sounds	- a pulsing "whoosh, whoosh, whoosh" at varying rates.
Engine Sounds	- various roars and rumbles, hums and whines, sometimes with a rhythmic pulsing and varying from low to high pitch.
Propeller Shaft squeal and hull resonance	- a squeal is high in pitch and resonance is a lower tone but both are regular and heard every 4th beat of the propeller.
Other Sounds	- Sonar 'pings' (i.e. regular bursts of tone at medium to high frequencies), mechanical clanks made by shipboard machinery.
Irrelevant Sounds	- Whistles, popping and crackling, grunts and groans generated by marine animals. General "sea noise", a rushing hissing sound.

This chart shows the types of sound associated with each type of ship.

	Propeller	Engine	Shaft and Resonance	Other relevant sounds
Warship	Fairly fast	Low to medium pitched roar or hum	Sometimes present	Sonar often present. Occasional clanks.
Cargo	Slow	Low rumble or roar	Often present	Sonar never present. Clanks common.
Submarine	Slow/ Medium	Usually a whine	Occasional squeal	Sonar occasionally present and some clanks
Light Craft	Fast	Usually high pitched hum or whine	Frequent shaft squeal	No sonar, occasional clanks.

APPENDIX C

TEST TAPE 1

TEST 1

ITEM	TYPE	PROPELLER	ENGINE	SHAFT SQUEAL OR HULL RESONANCE	OTHER SOUNDS
1	WARSHIP	FAIRLY FAST	LOW PULSED HUM	MEDIUM PITCH SQUEAL	SONAR
2	L.CRAFT	FAST	HIGH PITCH BUZZ	HIGH PITCH SQUEAL	CLANKS - SHRIMPS
3	WARSHIP	FAIRLY FAST	LOW PULSED HUM	MEDIUM PITCH SQUEAL	SONAR - CLANKS
4	SUB	MEDIUM SLOW	MEDIUM PITCH WHINE	NIL	CLANKS - PORPOISES
5	CARGO	SLOW	LOW RUMBLE	LOW PITCH RESONANCE	CLANKS - CARPENTER FISH
6	L.CRAFT	FAST	LOW PITCH BUZZ	MEDIUM PITCH SQUEAL	CLANKS - WHALES
7	L.CRAFT	FAST	HIGH PITCH WHINE	HIGH PITCH SQUEAL	CLANKS - PORPOISES
8	SUB	MEDIUM SLOW	MEDIUM PITCH WHINE	HIGH PITCH SQUEAL	SONAR
9	WARSHIP	FAIRLY FAST	LOW ROAR	HIGH PITCH SQUEAL	SONAR - WHALES
10	SUB	MEDIUM SLOW	HIGH WHINE	NIL	CLANKS - SONAR
11	CARGO	VERY SLOW	LOW RUMBLE	MEDIUM PITCH SQUEAL	CLANKS
12	SUB	SLOW	PULSING BUZZ	HIGH PITCH SQUEAL	NIL
13	SUB	MEDIUM SLOW	HIGH PITCH BUZZ	NIL	SONAR - CLANKS
14	L.CRAFT	FAST	MEDIUM PITCH WHINE	HIGH PITCH SQUEAL	CLANKS - CARPENTER FISH
15	WARSHIP	FAST	LOW HUM	HIGH PITCH SQUEAL	CLANKS
16	CARGO	SLOW	LOW RUMBLE	LOW PITCH RESONANCE	PORPOISES
17	CARGO	FAIRLY SLOW	MEDIUM PITCH RUMBLE	LOW PITCH RESONANCE	CLANKS - WHALES
18	CARGO	VERY SLOW	MEDIUM PITCH RUMBLE	MEDIUM PITCH RESONANCE	NIL
19	L.CRAFT	FAST	MEDIUM PITCH RUMBLE	HIGH PITCH SQUEAL	CLANKS
20	WARSHIP	MEDIUM FAST	LOW PITCH HUM	MEDIUM PITCH SQUEAL	SONAR - PORPOISES

TEST TAPE 1

	TYPE	PROPELLER	ENGINE	SHAFT SQUEAL OR HULL RESONANCE	OTHER SOUNDS
41	CARGO	MEDIUM SLOW	LOW ROAR	MEDIUM PITCH SQUEAL	CLANKS (VERY FAINT)
42	SUB	MEDIUM SLOW	WHINE	NIL	SONAR PING
43	SUB	SLOW	LOW WHINE/ROAR	HIGH PITCH SQUEAL	CLANKS
44	L.C.	FAST	HIGH PULSING BEATS	NIL	NIL
45	SUB	MEDIUM	WHINE	HIGH SQUEAL	CLANKS AND SONAR
46	L.C.	FAST	HIGH PULSING WHINE	HIGH SQUEAL	CARPENTER FISH
47	CARGO	MEDIUM SLOW	LOW RUMBLE	LOW HULL RESONANCE	NIL
48	SUB	SLOW MEDIUM	HIGH WHINE	NIL	SHRIMPS
49	L.C.	FAST	HIGH PULSED	HIGH PITCH SQUEAL	CLANKS
50	L.C.	FAST	PULSING WHINE	NIL	CLANKS
51	WARSHIP	FAIRLY FAST	LOW ROAR	NIL	PORPOISES - SONAR
52	CARGO	SLOW	LOW ROAR	MEDIUM PITCH SQUEAL	WHALES
53	WARSHIP	FAIRLY FAST	LOW PULSING ROAR	HIGH PITCH SQUEAL	WHALES - SONAR
54	CARGO	SLOW	LOW HUM	HIGH PITCH SQUEAL	CLANKS
55	WARSHIP	FAIRLY FAST	MEDIUM HUM	MEDIUM PITCH SQUEAL	SHRIMPS - SONAR
56	SUB	MEDIUM	WHINE	NIL	CLANKS - SONAR
57	WARSHIP	FAIRLY FAST	PULSING HUM	MEDIUM PITCH SQUEAL	SONAR
58	WARSHIP	FAIRLY FAST	LOW PULSING ROAR	MEDIUM PITCH SQUEAL	SONAR
59	L.C.	FAST	LOW HUM	HIGH PITCH SQUEAL	CLANKS - SHRIMPS
60	CARGO	SLOW	LOW PULSED ROAR	HIGH PITCH SQUEAL	CLANKS - PORPOISES

APPENDIX D

ERIC

COMPLEX SOUNDS | TEST TAPE 4. | ANSWER TEST SHEET

SUBJECT NO. ________ TEST NO. 1 ________ DATE ________

INSTRUCTIONS: All sounds are classified as Warship (W), Cargoship (C), Submarine (S) or Light Craft (LC). A fresh item is presented every 25 seconds. There will be a pause after item 30, again after 50 and after item 60. Follow the items on the test sheet and try not to lose your place. The training items 1-20 are alternately warship and light craft. Check these off as you hear them. Items 21-30 are test items and can be either warship or light craft. You must try to identify these by writing W or LC against the appropriate item number. Training items 31-50 are alternately cargoship and submarine and items 51-60 are test items which you must identify as either C or S. Finally the test items 61-80 can be W, C, S or LC, i.e. any of the 4 categories you have heard. If you do not know the answers you must guess.

Item No.	Class	Item No.	Class	Item No.	Class	Item No.	Class
1	W	21		41	C	61	
2	LC	22		42	S	62	
3	W	23		43	C	63	
4	LC	24		44	S	64	
5	W	25		45	C	65	
6	LC	26		46	S	66	
7	W	27		47	C	67	
8	LC	28		48	S	68	
9	W	29		49	C	69	
10	LC	30		50	S	70	
11	W	31	C	51		71	
12	LC	32	S	52		72	
13	W	33	C	53		73	
14	LC	34	S	54		74	
15	W	35	C	55		75	
16	LC	36	S	56		76	
17	W	37	C	57		77	
18	LC	38	S	58		78	
19	W	39	C	59		79	
20	LC	40	S	60		80	

APPENDIX E

ERIC

TEST TAPE 4.

Test 1

ITEM	TYPE	PROPELLER	ENGINE	SHAFT SQUEAL OR HULL RESONANCE	OTHER SOUNDS
1	WARSHIP	FAIRLY FAST	LOW PULSED HUM	MEDIUM PITCH SQUEAL	SONAR
2	L. CRAFT	FAST	HIGH PITCH BUZZ	HIGH PITCH SQUEAL	SHRIMPS - CLANKS
3	WARSHIP	FAIRLY FAST	LOW PULSED HUM	MEDIUM PITCH SQUEAL	SONAR - CLANKS
4	L. CRAFT	FAST	LOW PITCH BUZZ	MEDIUM PITCH SQUEAL	WHALES - CLANKS
5	WARSHIP	FAIRLY FAST	LOW PITCH ROAR	HIGH PITCH SQUEAL	SONAR - WHALES
6	L. CRAFT	FAST	HIGH PITCH WHINE	HIGH PITCH SQUEAL	PORPOISES - CLANKS
7	WARSHIP	FAST	LOW PITCH HUM	HIGH PITCH SQUEAL	CLANKS
8	L. CRAFT	FAST	MEDIUM PITCH WHINE	HIGH PITCH SQUEAL	CARPENTER FISH - CLANKS
9	WARSHIP	MEDIUM FAST	LOW PITCH HUM	MEDIUM PITCH SQUEAL	SONAR - PORPOISES
10	L. CRAFT	FAST	MEDIUM PITCH RUMBLE	HIGH PITCH SQUEAL	CLANKS
11	WARSHIP	MEDIUM FAST	LOW PULSED ROAR	HIGH PITCH SQUEAL	SONAR
12	L. CRAFT	FAST	MEDIUM PULSED WHINE	MEDIUM PITCH SQUEAL	WHALES
13	WARSHIP	MEDIUM FAST	LOW PULSED ROAR	MEDIUM PITCH SQUEAL	CARPENTER FISH - CLANKS
14	L. CRAFT	FAST	MEDIUM PULSED BUZZ	NIL	CLANKS
15	WARSHIP	FAIRLY FAST	LOW PULSED HUM	MEDIUM PITCH SQUEAL	SONAR
16	L. CRAFT	FAST	MEDIUM PITCH BUZZ	HIGH PITCH SQUEAL	NIL
17	WARSHIP	FAIRLY FAST	LOW PITCH ROAR	HIGH PITCH SQUEAL	SONAR
18	L. CRAFT	FAST	MEDIUM PULSED HUM	NIL	SHRIMPS
19	WARSHIP	MEDIUM FAST	LOW PULSED HUM	MEDIUM PITCH SQUEAL	CLANKS
20	L. CRAFT	FAST	MEDIUM PITCH ROAR	MEDIUM PITCH SQUEAL	PORPOISES - CLANKS

TEST TAPE 4.

Test 1

ITEM	TYPE	PROPELLER	ENGINE	SHAFT SQUEAL OR HULL RESONANCE	OTHER SOUNDS
31	CARGO	SLOW	LOW PITCH RUMBLE	LOW PITCH RESONANCE	CARPENTER FISH - CLANKS
32	SUB	MEDIUM SLOW	MEDIUM PITCH WHINE	HIGH PITCH SQUEAL	SONAR
33	CARGO	VERY SLOW	LOW PITCH RUMBLE	MEDIUM PITCH SQUEAL	CLANKS
34	SUB	MEDIUM SLOW	HIGH PITCH WHINE	NIL	SONAR - CLANKS
35	CARGO	SLOW	LOW PITCH RUMBLE	LOW PITCH RESONANCE	PORPOISES
36	SUB	SLOW	PULSING BUZZ	HIGH PITCH SQUEAL	NIL
37	CARGO	FAIRLY SLOW	MEDIUM PITCH RUMBLE	LOW PITCH RESONANCE	WHALES - CLANKS
38	SUB	MEDIUM SLOW	MEDIUM PITCH WHINE	NIL	PORPOISES - CLANKS
39	CARGO	VERY SLOW	MEDIUM PITCH RUMBLE	MEDIUM PITCH RESONANCE	NIL
40	SUB	MEDIUM SLOW	HIGH PITCH BUZZ	NIL	SONAR - CLANKS
41	CARGO	SLOW	LOW PULSED ROAR	MEDIUM PITCH SQUEAL	SHRIMPS - CLANKS
42	SUB	SLOW	MEDIUM PITCH WHINE	NIL	WHALES
43	CARGO	SLOW	MEDIUM PULSED HUM	MEDIUM PITCH SQUEAL	CLANKS
44	SUB	MEDIUM SLOW	HIGH PITCH WHINE	HIGH PITCH SQUEAL	SONAR
45	CARGO	VERY SLOW	LOW PITCH RUMBLE	HIGH PITCH SQUEAL	WHALES
46	SUB	SLOW	LOW PITCH WHINE	HIGH PITCH SQUEAL	CARPENTER FISH - CLANKS
47	CARGO	FAIRLY SLOW	LOW PITCH RUMBLE	LOW PITCH RESONANCE	SHRIMPS - CLANKS
48	SUB	MEDIUM SLOW	HIGH PITCH BUZZ	NIL	SONAR
49	CARGO	VERY SLOW	LOW PULSED ROAR	LOW PITCH RESONANCE	CARPENTER FISH - CLANKS
50	SUB	MEDIUM SLOW	HIGH PITCH WHINE	HIGH PITCH SQUEAL	CLANKS

APPENDIX F

ERIC

COMPLEX SOUNDS | TEST TAPE 2B | ANSWER TEST SHEET

GROUP 1b.

SUBJECT No.________ TEST No. 2 DATE________

INSTRUCTIONS: All sounds are classified as Warship (W), Cargoship (C), Submarine (S) and Light Craft (LC). A fresh item is presented every 25 seconds preceded by an item number. Follow the items on the test sheet and try not to lose your place. Check off the training items 1-20 and 41-60 as you hear them. Identify the test items 21-40 and 61-80 by writing W, C, S or LC against the item number. If you don't know you must guess. There will be a short pause after each 20th item to check that you have not lost your place.

Item No.	Class	Item No.	Class	Item No.	Class	Item No.	Class
1	W	21		41	W	61	
2	S	22		42	S	62	
3	LC	23		43	W	63	
4	C	24		44	LC	64	
5	W	25		45	S	65	
6	W	26		46	C	66	
7	S	27		47	W	67	
8	LC	28		48	C	68	
9	S	29		49	S	69	
10	C	30		50	S	70	
11	W	31		51	W	71	
12	S	32		52	W	72	
13	S	33		53	LC	73	
14	LC	34		54	S	74	
15	W	35		55	LC	75	
16	C	36		56	W	76	
17	S	37		57	S	77	
18	W	38		58	C	78	
19	W	39		59	W	79	
20	S	40		60	S	80	

APPENDIX G

ERIC

	PROPELLERS										ENGINES							OTHER SHIP SOUNDS					
	CAVITATION RATE				PITCH				SYNC		PITCH			PULSED		RHYTHM							
	SLOW	MEDIUM SLOW	MEDIUM FAST	FAST	LOW	MEDIUM	HIGH	VERY HIGH	SYNC	ASYNC	LOW	MEDIUM	HIGH	YES	NO	YES	NO	SONAR	FLAPPER VALVES	SHAFT SQUEAL	HULL R/ANCE	MACHINERY CARGO OR HOLD SOUNDS	CLASS
1		✓					✓		✓			✓		✓			✓	✓	✓				S
2			✓			✓			✓		✓			✓			✓	✓		✓			W
3				✓				✓	✓				✓	✓			✓			✓		✓	LC
4	✓				✓				✓		✓			✓			✓				✓	✓	C
5				✓				✓	✓				✓	✓			✓			✓		✓	LC
6		✓					✓			✓		✓			✓	✓			✓				S
7			✓			✓			✓		✓			✓		✓		✓		✓			W
8	✓				✓				✓		✓			✓		✓				✓			C
9				✓				✓	✓			✓			✓	✓				✓			LC
10		✓					✓		✓		✓				✓	✓			✓	✓			S
11																							
12																							
13																							
14																							
15																							
16																							
17																							
18																							
19																							
20																							

APPENDIX H

ERIC

PROPELLERS										ENGINES							OTHER SHIP SOUNDS				
CAVITATION RATE				PITCH				SYNC		PITCH			PULSED		RHYTHMIC						
SLOW	MEDIUM SLOW	MEDIUM FAST	FAST	LOW	MEDIUM	HIGH	VERY HIGH	SYNC	ASYNC	LOW	MEDIUM	HIGH	YES	NO	YES	NO	SONAR	FLAPPER VALVES	SHAFT SQUEAL	HULL RESONANCE	MACHINERY CARGO OR HOLD SOUNDS
0	0	***	0	0	***	0	0	***	0	***	0	0	**	*	**	*	**	0	**	0	*
***	0	0	0	***	0	0	0	***	0	***	0	0	**	*	**	*	0	0	**	**	**
0	***	0	0	0	0	***	0	**	*	*	**	*	*	**	**	*	**	**	*	0	0
0	0	0	***	0	0	0	***	***	0	*	*	**	**	*	*	**	0	0	**	0	**

*** ALWAYS = 100%

** OFTEN = 50% approx.

* SOMETIMES = Less than 50%

0 NEVER

SHEET 1.

CLASSIFICATION CUE CHART

APPENDIX I

ERIC

	PROPELLERS										ENGINES							OTHER SHIP SOUNDS					
	CAVITATION RATE				PITCH				SYNC		PITCH			PULSED		RHYTHM							
	SLOW	MEDIUM SLOW	MEDIUM FAST	FAST	LOW	MEDIUM	HIGH	VERY HIGH	SYNC	ASYNC	LOW	MEDIUM	HIGH	YES	NO	YES	NO	SONAR	FLAPPER VALVES	SHAFT SQUEAL	HULL R/ANCE	MACHINERY CARGO OR HOLD SOUNDS	CLASS
1		✓					✓		✓			✓		✓			✓	✓	✓				S
2			✓			✓			✓		✓			✓			✓	✓		✓			W
3				✓				✓	✓				✓	✓			✓			✓		✓	LC
4	✓				✓				✓		✓			✓			✓				✓	✓	C
5				✓				✓	✓				✓	✓			✓			✓		✓	LC
6		✓					✓			✓		✓			✓	✓			✓				S
7			✓			✓			✓		✓			✓		✓		✓		✓			W
8	✓				✓				✓		✓			✓		✓				✓			C
9				✓				✓	✓			✓			✓	✓				✓			LC
10		✓					✓		✓		✓				✓	✓			✓	✓			S
11																							
12																							
13																							
14																							
15																							
16																							
17																							
18																							
19																							
20																							

APPENDIX J

ERIC

CLASSIFICATION CUE CHART

SHEET 1

PROPELLERS

CAVITATION RATE	PITCH	CLASS
SLOW	LOW	C
MEDIUM FAST	MEDIUM	W
MEDIUM SLOW	HIGH	S
FAST	VERY HIGH	LC

C = CARGOSHIP

W = WARSHIP

S = SUBMARINE

LC = LIGHTCRAFT

ERIC

APPENDIX K

ERIC

SHEET 1

CLASSIFICATION CUE CHART

CLASS	PROPELLERS		ENGINE	OTHER SHIP SOUNDS			
	CAVITATION RATE	PITCH	PITCH	SONAR	SHAFT SQUEAL	CARGO & MACHINERY	FLAPPER VALVES
CARGOSHIP	slow	low	always low	never	often	often	never
WARSHIP	medium fast	medium	always low	often	often	sometimes	never
SUBMARINE	medium slow	high	often medium	often	sometimes	never	often
LIGHTCRAFT	fast	very high	often high	never	often	often	never

ALWAYS

ALWAYS = 100%
OFTEN = 50% approx.
SOMETIMES = less than 50%
NEVER = 0%

APPENDIX L

ERIC

CLASSIFICATION EXERCISE SHEET 2. NAME ____________

	PROPELLERS								ENGINE			OTHER SHIP SOUNDS				
	CAVITATION RATE				PITCH				PITCH							
ITEM	SLOW	MED. SLOW	MED. FAST	FAST	LOW	MEDIUM	HIGH	VERY HIGH	LOW	MEDIUM	HIGH	SONAR	SHAFT SQUEAL	MACHINERY OR CARGO	FLAPPER VALVES	CLASS
1	✓				✓				✓				✓			C
2			✓			✓			✓			✓	✓			W
3		✓					✓			✓					✓	S
4				✓				✓			✓		✓	✓		LC
5		✓					✓			✓		✓	✓			S
6				✓				✓			✓		✓			LC
7	✓				✓				✓					✓		C
8			✓			✓			✓			✓		✓		W
9		✓					✓				✓	✓			✓	S
10			✓			✓			✓				✓	✓		W
11				✓				✓			✓		✓	✓		
12		✓					✓			✓		✓			✓	
13	✓				✓				✓				✓	✓		
14			✓			✓			✓			✓	✓			
15		✓					✓				✓	✓	✓			
16				✓				✓		✓				✓		
17	✓				✓				✓				✓			
18			✓			✓			✓				✓	✓		
19		✓					✓		✓			✓			✓	
20				✓				✓			✓		✓	✓		
21		✓				✓				✓		✓			✓	
22				✓		✓			✓							
23	✓						✓			✓		✓			✓	
24		✓			✓				✓				✓	✓		
25				✓			✓				✓		✓			
26			✓			✓			✓			✓			✓	
27	✓				✓				✓			✓	✓		✓	
28		✓				✓					✓	✓	✓		✓	
29		✓				✓			✓					✓		
30				✓				✓			✓	✓	✓	✓	✓	

ERIC

APPENDIX M

ERIC

EXTRA INSTRUCTIONS

Not all the components are equally helpful in classifying the sounds into the four types of ship, because most of them are not definitely linked to one certain type.

The number behind the components is a measure (ranging from 0 to 100), which tells you in how many percent of the cases you would be correct if you identified this component correctly.

For example, if you got the propeller right (speed or pitch) your classification is, in 100% of the cases, correct. But if you can't hear the propeller very well, because it is masked by the sea-noise (which is always present) and listen instead to the pitch of the engine sound, you can only be correct in 24% of the cases.

Of course you need not listen to only one component.

Propeller: 100%
The propeller (speed as well as pitch) is the only component from which you can tell the type of ship in every case.

Engine: 24%
Identifying correctly the pitch of the engine you will be right in 24% of the cases.

Shaftsqueal: 10%
All the ships may or may not have shaftsqueal, so it does not help you much.

Mechanical Sounds: 19%
Not of much help. All types may have it.

Sonar: 39%
After the propeller this is the best clue for classification, because cargoship and lightcraft never have it whereas warship and submarine often have sonar pings.

	PROPELLER		ENGINE	OTHER SHIP SOUNDS		
	SPEED	PITCH	PITCH	SHAFT SQUEAL	MECHANICAL SOUNDS	SONAR
CARGOSHIP	slow	low	low	often	often	never
WARSHIP	medium fast	medium	low	often	sometimes	often
SUBMARINE	medium slow	high	mostly medium	sometimes	often	often
LIGHTCRAFT	fast	very high	mostly high	often	often	never

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13. ABSTRACT A series of experiments is described in which 15 methods of teaching identification of complex sonar-like sounds were compared. These included whole and part methods in which subjects were trained on samples of whole sounds, received pre-training on components of the sounds or were exposed to components in the context of whole sounds. The conditions included variations in order in which training items were presented and in the kinds of verbal instruction given.

Overall the various part methods were not superior to training on whole sound items. The best of the part methods drew attention to only one feature of the whole sound. Some systematic orderings of presentations showed no advantage over random order presentation. Verbal instruction drawing attention to cues and their value in classification did not prove effective.

Among the various combinations of training procedures and state-of-the-art training techniques, the critical ingredient seems to be amount of exposure to instances of the recognition classes to be learned. Before further refinement in the training of this skill can be achieved a greater understanding of human perceptual learning is required.

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	ROLE	WT	ROLE	WT	ROLE	WT
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